Introduction

Yokoshi [2004] measured the electrical conductivity of \((\text{Mg}_{0.9}\text{Fe}_{0.1})\text{SiO}_3\) ilmenite at high pressures (25 GPa ~ 35 GPa) and temperatures (300 K ~ 1300 K), and found a very large pressure dependence of the electrical conductivity of this mineral. We measure electrical conductivity of FeTiO\(_3\) ilmenite as the structural analogue of \((\text{Mg}_{0.9}\text{Fe}_{0.1})\text{SiO}_3\) ilmenite.

Experimental

Sample synthesis

FeTiO\(_3\) ilmenite was synthesized from a mixture of Fe\(_2\)O\(_3\) and TiO\(_2\) powders. We dried the reagent of Fe\(_2\)O\(_3\) and TiO\(_2\) at 1100°C for 24h, and then mixed and ground the two powders in a motor for about 40 minutes. The weight ratio of starting material is Fe\(_2\)O\(_3\) : TiO\(_2\) = 1 : 1.01 (Fe\(_2\)O\(_3\) = 1.570 g, TiO\(_2\) = 1.582 g) so that the sample should contain small amount of excess TiO\(_2\) rather than iron oxide. We made the mixture to a disk with 10 mm in diameter and 5-10 mm in length, and heated it in a gas-mixing furnace at 1200°C for 3 h with total gas amount of 400cc and CO\(_2\):H\(_2\) ratio of 152:248. After that, we quenched the sample into water. We opened the disk to separate the core and rim of the sample. We examine these two parts by powder X-ray diffraction. We found that the core and rim are composed of FeTiO\(_3\) only and FeTiO\(_3\)+Fe\(_2\)TiO\(_5\), respectively. We use the core part for the electrical conductivity measurement.

Electrical conductivity measurements

Experiments were performed using a KAWAI-type multi-anvil high-pressure apparatus (USSA-5000). Tungsten carbide anvils with edge length of 32.4 mm and truncated edge length of 7.0 mm were used as second-stage anvils. An octrahedral pressure medium was composed of MgO +5% Cr\(_2\)O\(_3\). Its distance between opposite faces is 11.31 mm. The edges of the pressure medium are cut so that the distance of the opposite edges is 11.66 mm. A hole with 3.0 mm in diameter are made in the center of the pressure medium face. Two folds of Ta foil with 13.5×18.0 mm length and 0.005 mm thickness were used as a heater. Temperature was measured using W/Re (3/25) thermocouple with 0.075/0.13 mm in diameter. Another W97%Re3% wire was placed as an electrode for electrical conductivity measurement. In run # 592, pressure of 2 GPa was applied to the sample. The sample temperatures were increased and decreased with 50
or 100 K step. In run # 592, pressures were increased from 4 to 16 GPa with 4 GPa step, and temperatures were increased or decreased between 300 and 600 K with 50 or 100 K. The signal amplitude of 1.0V and frequency of 0.1Hz was applied on the circuit. Reference resistance was 100 Ω.

**Result and Discussion**

Fig.1 shows the electrical conductivity of FeTiO$_3$ ilmenite at 4 GPa, 8 GPa, 12 GPa and 16 GPa. The behavior of these curves suggest that FeTiO$_3$ ilmenite is semiconductor because the conductivity increases with increasing temperature.

Fig. 1 also indicate that the electrical conductivity increases with increasing pressure. The measured conductivity is fitted to the Arrhenius’ form:

$$
\sigma = \sigma_0 \exp \left( -\frac{E}{kT} \right)
$$

where, $\sigma$ is the electrical conductivity at temperatures, $\sigma_0$ is the electrical conductivity at infinitely high temperature, $E$ is the activation energy, and $k$ is the Boltzmann constant. As is shown in Table 1, the activation energy $E$ (eV) decreases with increasing pressure (from 8 GPa to 16 GPa). However, this is not because the concentration of electron was changed at high pressure and temperature by oxidation of Fe$^{2+}$ to Fe$^{3+}$. The temperatures were too low for oxidation (600 K at maximum). These results suggest that FeTiO$_3$ electrical conductivity have small pressure dependence.

<table>
<thead>
<tr>
<th>Pressure (GPa)</th>
<th>$E$ (eV)</th>
<th>$\sigma$ (S/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>0.190</td>
<td>1.77E+03</td>
</tr>
<tr>
<td>12</td>
<td>0.185</td>
<td>2.00E+03</td>
</tr>
<tr>
<td>16</td>
<td>0.181</td>
<td>2.55E+03</td>
</tr>
</tbody>
</table>

Table 1 Arrhenius plots for FeTiO$_3$ ilmenite at 8 GPa, 12 GPa, 16 GPa

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![Ahrenius plot of electrical conductivity of FeTiO$_3$ ilmenite. Measurement was conducted at](image-url)
4 GPa, 8 GPa, 12 GPa and 16 GPa

Acknowledgements

BhZ thanks Hiroshi Fukui, Sho Yokoshi, Han-wei Huang, Shuangmeng Zhai, Qingqing Liu, and Xiaomei Qin for their detailed assistance, suggestions and discussions. This study has been carried out during the Misasa International Intern Program 2005, supported by the COE-21 program from the Ministry of Education, Culture, Sports, Science and Technology of Japan.